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research trends

CORNELL AERONAUTICAL LABORATORY, INC., *of Cornell University*
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AIR TRAFFIC CONTROL

Moving Aircraft Safely and Quickly

by Dr. ALFRED BLUMSTEIN

IMAGINE two jet airliners five miles apart on head-on collision courses. The pilots have only fifteen seconds to prevent a collision — assuming they can see each other at that distance. In that time each must decide on and initiate an evasive maneuver to correct the situation.

When clouds reduce visibility below five miles or when the pilots are distracted by instruments, lunch, or other crew members, or when they are looking in any direction other than at the oncoming aircraft, the available time is reduced. To compensate for the limited time the pilot has in which to react — limited by short detection ranges in bad weather and by high closure rates even in good weather — we need a system of air traffic control on the ground to guard against collisions.

Present System of ATC

Air traffic control is at present exercised by means of two sets of rules: Visual Flight Rules (VFR), used only when visibility is good, and Instrument Flight Rules, (IFR) followed under poorer weather conditions.

(Photo courtesy of General Precision)

Typical scene in present-day Air Route Traffic Control Center showing controllers following aircraft on radar scope, manually "tracking" such aircraft with cardboard models, updating Flight Progress Strips by hand.

VFR is based on a concept of "see-and-be-seen" under which pilots alone are responsible for avoiding collisions. IFR rules compensate for the limitations on the pilots' ability to see by investing this responsibility in the control system. The control system surrounds each aircraft with a volume of airspace from which it excludes all other aircraft also operating under control. This protective zone is large enough to allow for errors in position information, and still leave sufficient time to react to a dangerous situation.

Any ATC system must perform four major functions. These are ***data collection*** to obtain knowledge of aircraft positions and intended flight paths, ***data processing*** to predict potential conflicts, ***decision making*** to select the best conflict resolution, and ***communication*** to direct the pilots involved. Today, the data collection is performed manually by trained controllers watching radar scopes and receiving pilots' oral reports by radio. Data processing and decision making are performed by controllers using hand-written records to evaluate conflicts. Communication is conducted by voice radio. Except for the application of radar, this system differs little from the one used twenty years ago. Equipment now being developed will automate much of the data processing and communication with properly equipped aircraft. All control decisions, however, will continue to be made by the versatile and flexible human controllers.

Enroute Control

Except in the vicinity of the destination airport, IFR control is effected along a network of "airways" and associated "fixes." These airways also serve as an electronically defined navigational "highway system;" the fixes are the crossroads. Before taking off, a pilot files a flight plan with the ATC system, indicating his airway route. His ***estimated time of arrival*** (ETA) at each of his fixes is determined from the flight plan. In the control center, each fix is monitored by a controller who maintains a record of ETA and altitude of each aircraft intending to pass there.

The controller checks to see that there is no conflict between arriving aircraft. A conflict occurs when two aircraft at the same altitude have ETA's differing by less than specified minimums — generally 10 minutes. A conflict is resolved by ordering one of the aircraft (generally the one with the later ETA) to hold its position or to change altitude.

Where enroute radar facilities are available, aircraft may be separated by as little as three miles, a much closer separation than the ten-minute requirement where 300-knot aircraft are separated by 50 miles and 600-knot aircraft by 100 miles.

Terminal-Area Control

In the vicinity of the major airports arriving aircraft are controlled by radar. When aircraft arrive faster than they can be landed, they await their landing turns in "stacks". Pilots in a stack fly a precise holding pattern over some radio facility while maintaining the standard 1000-foot altitude separation from other waiting aircraft. As soon as an aircraft is landed from the bottom of the stack, the remainder are laddered down one level . The path flown from the stack to the runway may be an approach in which the radar controller vectors the pilot into position for the final maneuver.

All landing aircraft follow a common final approach path to the runway during which they must maintain the three-mile radar separation along the path, or at least at its beginning. Furthermore, since two aircraft may not occupy the runway at the same time, an aircraft may not be landed unless its predecessor has left the runway.

Growth of ATC

Air traffic control appeared relatively recently in the development of aviation. Lack of electronic navigation capability limited early flying to clear weather. Pilots flew at slow speeds, and worried little about collision with the few other aircraft operating.

Electronic developments prior to and during World War II greatly improved air navigation capability. This, and the growth of aviation, created a post-war demand for far more sophisticated ATC. To decide how best to meet the demand, a far-reaching study was undertaken in 1947 by the Radio Technical Commission for Aeronautics. This study resulted in a comprehensive plan for a common military-civil ATC system to be developed in two phases: a transition phase to have been completed by 1953, and an ultimate phase to be completed by 1963. The present ATC system resembles the recommended ***transition*** system in most respects, except that the transition is not yet complete.

Implementation of the committee's recommendations was made most difficult by conflicting needs of the various airspace users and by lack of a central aviation authority in the government. At one point,

over 75 governmental agencies were concerned with aviation facilities, and no single one was sufficiently powerful to withstand the pressures from the special interest groups in aviation, each of which had its own ideas about the best system to develop, based on its own characteristic needs.

The problem of fragmented authority was ultimately resolved in 1958 by the creation of the Federal Aviation Agency. In this one organization was consolidated exclusive authority to control air traffic, to certify aircraft and pilots, and to develop and install air navigation and air traffic control facilities.

The primary responsibility for improving the ATC system lies with the FAA's Bureau of Research and Development. Its main effort is directed at several equipment developments. Data-processing equipment will relieve the controller of many of his menial tasks and permit him to devote more attention to the air traffic situation. Automatic air-ground communications equipment will reduce the time spent in talking on the radio and reduce the required number of radio channels. A safe automatic landing system to permit a hands-off landing to touchdown will reduce the number of occasions an airport is closed by weather.

Systems Research Needed

In addition to equipment development, an extensive program of systems research is needed to aim the hardware programs in the most promising directions, and to show how the components can best be organized to provide optimum system performance. ATC performance is measured both by the degree of protection provided and by the delay penalty inflicted. The current system has an unmarred safety record: no two aircraft, both under ATC control, have ever collided. This leaves reduction of delay the major problem.

Delay is experienced during busy periods when the demand for control temporarily exceeds the ATC system's capacity. The IFR demand in clear as well as in cloudy weather has increased appreciably in recent years. The increase results from both a growing capability to accept control and a growing desire for the protection it provides. More aircraft are equipped with necessary instrumentation and more pilots are trained to operate under IFR direction. "See-and-be-seen" has become obsolete as a means of avoiding collisions. Airplanes are moving too fast to "be seen," and pilots are too busy with navigation charts and instruments to "see." Yet, despite the growing demand, little has yet been done to increase the ATC system's capacity to serve it, so that the air traveler suffers ever-increasing delay.

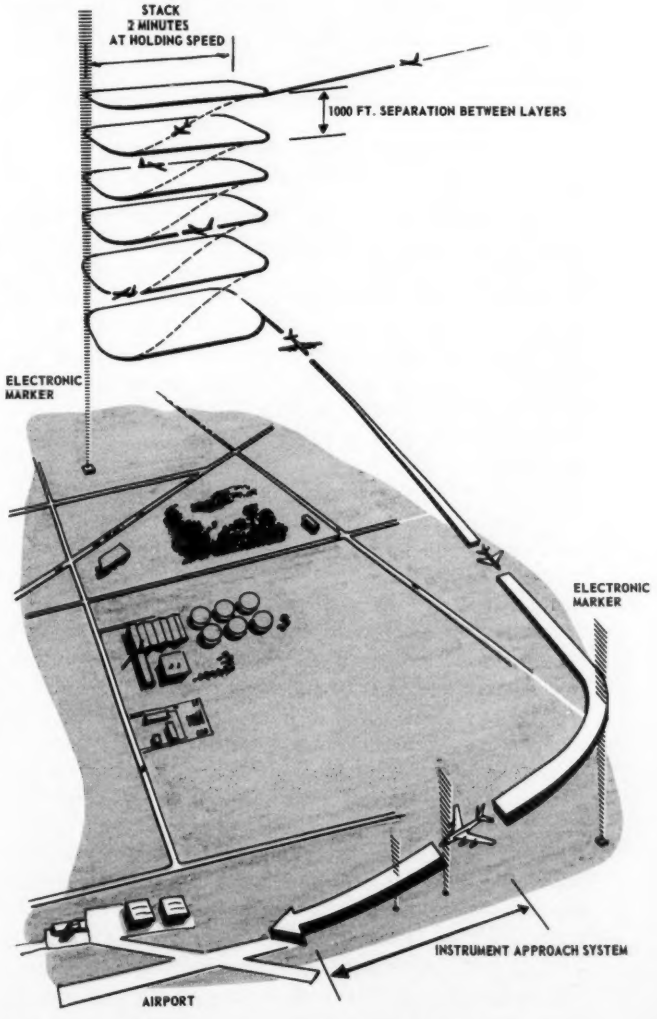
CAL Studies of Capacity

Recently studies at Cornell Aeronautical Laboratory have been directed at better understanding the capacity problem, in the hope of indicating how best to increase capacity and reduce delay.

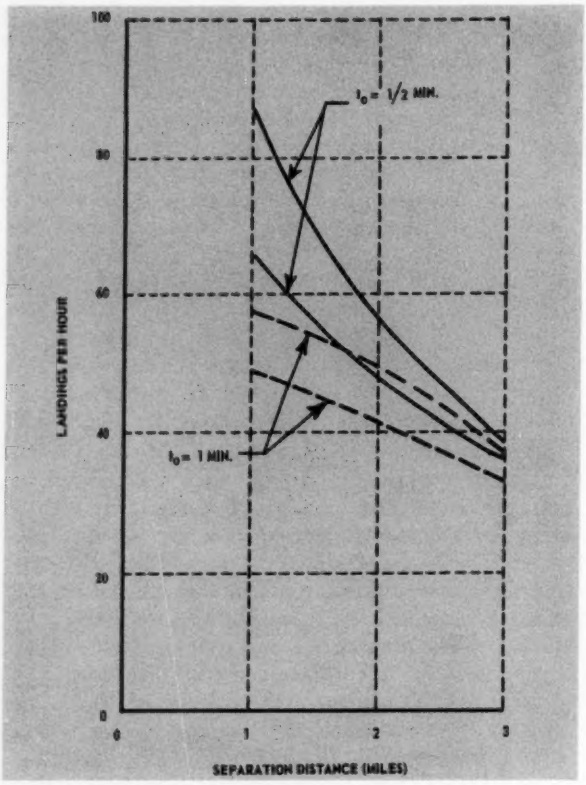
Experience indicates that delay occurs most often while waiting to land. A digital simulation of ATC operation developed by IBM also indicated that this is the crux of the problem. CAL analysis of the results showed that landing delay accounted for three-quarters of the total delay time accumulated in the New York area during a sample heavy-traffic two-hour period.

Since most of this delay is experienced in the stacks, many new ATC systems have been proposed in which elaborate pains have been taken to eliminate the stacks. But this is comparable to removing the chairs from a doctor's waiting room in the hope of reducing the wait. The delay can best be reduced by providing for increased service capacity, and where or how the delay is experienced is irrelevant.

The simulation indicated that at the heart of the delay problem was the airport landing capacity. Doubling the landing capacity of the airports in the simulation reduced the landing delay by over 60%. Additional study was then directed at the problem of runway capacity. Working with Laboratory internal research funds, analytical models (or sets of equations) were formulated to describe runway landing capacity as a function of the parameters characterizing the runway operating procedures and the arriving traffic. The models helped to bring into focus long-standing ATC questions.



Arriving airplanes await their turn to land in stacks.



Landing rate is most critically dependent on separation distance.

Model Results

The studies show that landing capacity is most severely restricted by the space separation required on the common landing path. The present three-mile requirement is based on the use of radar, and was set about ten years ago as a value that provided a reasonable degree of safety consistent with the demand for service. It may be that the same degree of safety can be achieved today with less separation by using more accurate radars and by reorganizing the controller's workload so that he can more readily detect any violation of a separation requirement.

High-speed turnoffs similar to a turnpike exit have been considered by many a solution to the problem of limited landing capacity. Such a turnoff permits an aircraft to leave the runway while it is still traveling as fast as 60 knots and thereby reduces its runway occupancy time. Since the basic runway separation requirement prevents two aircraft from using the runway at the same time, it is argued that the landing capacity would be increased accordingly. This increase would, in fact, occur during VFR conditions, when aircraft line up behind each other in close formation so that the following aircraft will touch the runway at about the time the preceding one is off — somewhat under a minute after it lands. But the capacity problem is most serious in IFR weather, and IFR rules prescribe a 3-mile minimum separation along the common landing path (equivalent to 1.5 minutes at 120 knots). The following aircraft is thus rarely in a position to land even after the preceding one has spent a full minute on the runway. When the space separation is reduced below two miles, then a real advantage will result from the use of the turn-offs, but little is gained under present procedures.

Sequencing has been proposed as a means of increasing landing capacity. Aircraft are now landed in a first-come-first-served sequence without regard to the consequences to the waiting aircraft or to the runway's landing rate. Thus, if the arrival sequence into a stack is "jet — DC-3 — jet," they are landed in that order, even though this leaves a large gap between the first jet and the DC-3, and imposes a relatively expensive delay on the second jet. It may appear from this example that some advantage would result from sequencing procedures which replaced the more democratic first-come service rule.

Analyses indicate that the over-all advantage in landing capacity that would accrue from rearrangement of the landing sequence is relatively small, (of the order of 10-20% even in an ideal case studied), so that if extensive effort were necessary to develop equipment and to initiate procedures to perform sophisticated sequencing, it might not be worth the effort. In the above example, the large gap avoided by sending the second jet before the DC-3 appears again when the DC-3 follows the second jet, thus negating the capacity advantage gained.

Since runways are generally used for take-offs as well as landings, additional models were formulated for an investigation of a runway's operations rate (rate of landings plus take-offs). Since most take-offs in a saturation situation are performed by interposing them between landings wherever possible, the operations rate represents the combined effect of the landing rate and the interposition rate. Most system parameters affect these two conversely. For example, reducing space separation raises the landing rate, but also provides less opportunity for interposing take-offs. Thus, the influence of any one of the system parameters depends strongly on the value of the others.

One factor that affects landing rate and interposition rate similarly is the runway-occupancy time. Thus, while a high-speed turnoff does little to increase ***landing*** capacity, it can raise the ***operations*** rate by removing the landing aircraft from the runway earlier, thereby making possible a take-off before the next landing gets too close. Similarly, sequencing techniques, which provide only a small contribution to landing capacity, may be effectively used to increase the interposition rate by creating landing intervals of such length as would permit the interposition of waiting take-offs.

These results are not conclusive proofs, since they follow from theoretical considerations rather than from controlled experimentation. They do, however, indicate where to look first when seeking to improve ATC operation. Further systems research will help the FAA in guiding its equipment development program and in evaluating quickly and inexpensively many possible alternative system configurations. This will bring closer the day when the air traveler will no longer be told: "All flights are subject to air traffic delays."

Airplanes . . . STRAIGHT UP!

The Aerodynamics of STOL and VTOL Aircraft*

by ROBERT J. VIDAL

During the fifty-odd years of its history, aircraft development has emphasized increased speed and range, invariably at the expense of take-off and landing distances. The fact that aircraft speeds have been increased by nearly an order of magnitude is truly remarkable. However, the attendant order of magnitude increase in take-off and landing distance is, at best, disconcerting.

We are faced now with a new aspect of the problem — that of maintaining high-speed, long-range abilities, while markedly decreasing ground-run distances to feet instead of miles. The helicopter has this desired low speed performance but lacks high-speed capability.

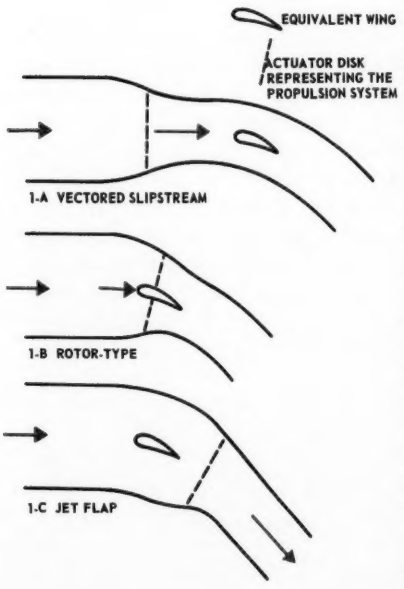


FIG. 1 — Generalized configurations.

The usual approach to this problem is to use the powerplant thrust to obtain lift at low speeds, as in the vectored slipstream and jet flap configurations. The former uses a highly flapped wing to turn a propeller slipstream through a large angle to obtain lift. The latter uses a thin jet for direct reaction life while obtaining beneficial interaction effects with the wing.

In these examples we can see the important departure from the classical approach. We have abandoned the distinction between lifting and thrusting systems and have combined them. One must then employ classical methods with considerable caution, recognizing that the two systems interact to determine performance.

In the following paragraphs we will examine the importance of these interactions between the lifting and thrusting systems, first by considering an elementary model of generalized configurations. Following this, detailed consideration will be given to the interactions peculiar to the jet flap and vectored slipstream configurations.

Generalized Configurations

There is a profusion of configurations being used for short take-off and landing applications. They include the helicopter, vectored slipstream, jet-flap, coleopter, ducted fan, tilting propeller, the tilting-wing/tilting-propeller and the wing-fan configurations. All differ in detail, but each employs interacting wing and thrust systems, and their gross properties can be described by elementary models (Fig. 1).

The identifying feature of the vectored slipstream configuration is that the powerplant, represented in Fig. 1a by an actuator disk, is set sufficiently forward of the wing system so that the wing operates in the fully developed slipstream. In the other extreme, an effective wing system is ahead of the thrusting system (Fig. 1c) so that the wing system is acted upon only by the remote stream. Between these two extremes is one in which the lifting and thrusting functions are so intermixed as to be individually indistinguishable. This model, Fig. 1b, represents rotor-type configurations, such as the helicopter, the ducted fan, and in certain cases the tilting propeller, and tilting-wing/tilting-propeller.

An infinite number of configurations could fall between the extremes in Fig. 1, differing only in the relative spacing of the effective wing system and the actuator disk. Their performance would, of course, change with this parameter, but the dominant parameter would still be the propulsive area, the area in which energy is added to the flow.

The importance of propulsive area is illustrated in Fig. 2, which shows the ideal power required for steady,

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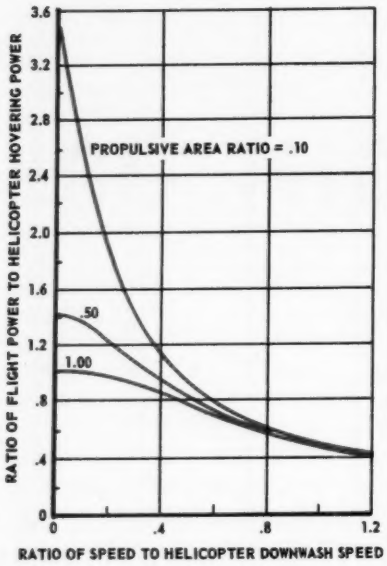

FIG. 2 — **Power requirements for generalized configurations.**

level flight for the rotor-type configurations. At high speeds, the power required is essentially independent of propulsive area, but at low speeds the propulsive area predominates. Now the power required does not by itself determine efficiency, but it provides a measure of configuration efficiency. Hence the more efficient configurations are those with the largest propulsive area.

The results in Fig. 2 do not rigorously apply to other than rotor-type configurations, and one might anticipate that a vectored slipstream configuration would require somewhat less power because the wing is immersed in the fully developed slipstream. Similarly, the jet flap configuration should require somewhat more power since its wing system is acted upon only by the remote stream velocity. However the qualitative trends in Fig. 2, and in particular the influence of propulsive area would be similar for these and other configurations. These results then indicate that, because of its thin jet, the jet flap configuration will be relatively inefficient in the low speed range.

The Jet Flap

Though the jet flap configuration does not appear promising, consideration of its singular aerodynamic features can lead to more efficient configurations.

By definition, the jet flap is a wing with a thin high-velocity jet directed from the trailing edge at an angle with respect to the remote stream. The jet then provides lift through direct reaction. However, experiments and theory show that a comparable amount of lift is also obtained through jet induced effects.

These induced effects on the wing stem from the curvature of the jet sheet under the action of the free stream. The jet, directed at an angle with respect to the stream, is subsequently deformed by the stream until it is aligned with the local stream. This requires that nearly all the jet momentum appear as thrust on the wing. More important, the jet curvature near the wing induces a flow over the wing to provide more lift and to delay the usual type of wing stall. It is found in experiments that lift coefficients in the order of 10 can be obtained at small angles of attack.

It is clear that it would be desirable to obtain a large induced lift with the expenditure of small energy in the jet. Examination of the jet flap shows that this condition is achieved when the jet velocity is small in comparison with the flight velocity. Now if the jet is required to provide both lift and thrust, it is found that this condition is achieved at high flight speeds. At low speeds, it is necessary to put a large amount of energy in the jet to obtain lift and to overcome the drag.

The beneficial aerodynamic effects of the jet flap, and their limitations, can be understood by comparing the performance of the jet flap with that of the equivalent conventional airplane. This can be assessed by comparing the ideal power required by two identical configurations: one propelled by a pure jet flap and the other by a jet of equal area not interacting with the wing, as in a conventional airplane. This comparison is made in Fig. 3 for a typical jet flap configuration. It can be seen that in high speed flight, the ideal power required by the jet configuration approaches that necessary for the conventional airplane. However, in the low speed range the jet flap power requirements are markedly less.

To illustrate, for a typical airplane at a flight velocity of 40 mph, the jet flap configuration requires less than half the ideal power of an equivalent conventional configuration. However, Fig. 3 also shows that the jet flap configuration requires about five times the power of the equivalent helicopter. The conclusion is that the pure jet flap configuration profits from highly beneficial interaction effects at low forward speeds. But, because it employs a very thin jet to obtain this effect and to furnish the thrust, it is a relatively inefficient device for low speed flight.

Though the pure jet flap may not prove useful for low speed flight, the fundamental concept might be useful. Two important features of this configuration are (1) it can achieve unusually large lift coefficients without suffering from wing stall, and (2) the jet thrust is largely recovered so as to decrease the net drag.

In contrast, the vectored slipstream configuration, with its highly flapped wing, experiences bad separation effects over the wing's upper surface. A desirable configuration might be a combination of the jet flap and the vectored slipstream. Here the jet flap would be used only to control separation on the wing, and relatively

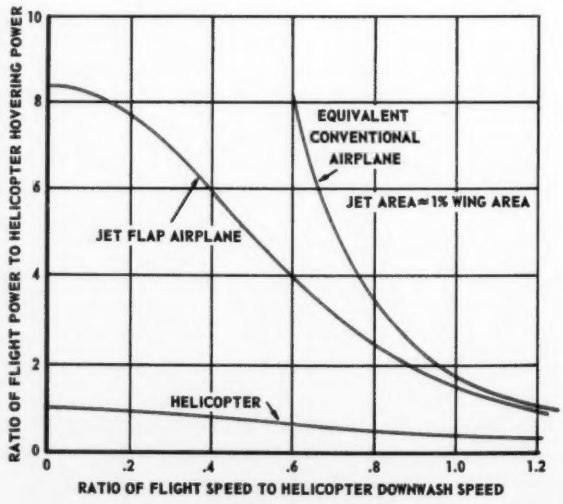

FIG. 3 — **Jet flap power requirements.**

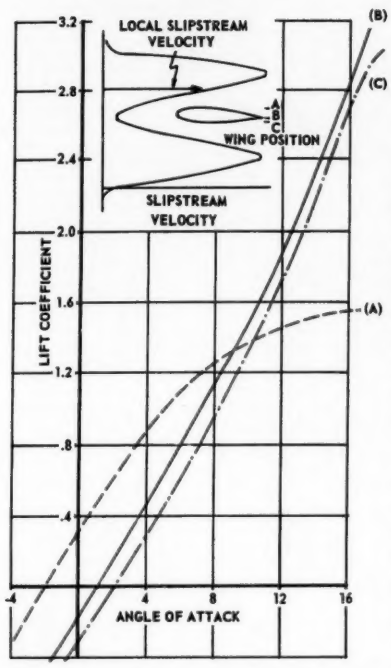

FIG. 4 — **Lift in a two-dimensional propeller slipstream.**

small jet momentum would be required. This is a desirable boundary layer control device, since nearly all jet momentum ultimately appears as thrust to augment the propeller thrust. However, the greatest portion of the thrust is obtained from the large area propeller, so that the configuration would be quite efficient. Further work on this mixed configuration must be done in order to quantitatively determine its feasibility.

Vectored Slipstream Configuration

As noted earlier, the identifying feature of the vectored slipstream configuration is that a highly flapped wing is used to turn a fully developed propeller slipstream through a large angle to obtain lift. Some of the aerodynamic processes taking place in this configuration are quite analogous to those in the jet flap configuration. In both instances a high velocity jet is turned, in one case by a nozzle and in the other by a wing, to flow at an angle with respect to the stream. In both instances the stream acts upon the jet locally to align it with the flow. Now in the case of the jet flap the stream acting upon the jet results in beneficial interactions with the wing. One might anticipate a similar state of affairs with the deflected slipstream configuration.

The important difference between the vectored slipstream and jet flap configurations is in the thickness of the jet. The vectored slipstream has one or several circular jets whereas the jet flap has a very thin jet. Indeed, the first approximation made in effecting a jet flap theory is to assume the jet is vanishingly thin, so that no consideration need be given to the internal jet structure. The opposite is true in the vectored slipstream configuration; that is, the details of the flow inside the final jet must reflect all the aerodynamic processes that occurred at the wing. Hence, the jet structure must be included in the problem solution.

The classical approach to the problem of a wing interacting with a slipstream is to first assume that the slipstream is uniform and is, for practical purposes, undeflected by the wing. In contrast, an actual propeller slipstream is characterized by very large radial gradients of velocity, and in passing over a highly flapped wing, is deflected through an angle approaching 90°. Recent research at Cornell Aeronautical Laboratory has been aimed at investigating the influence of these factors on performance.

The classical theory has been reformulated, neglecting slipstream velocity gradients, to determine the influence of the curved slipstream on configuration performance. This work, still in progress, shows that the deflected slipstream contains important "secondary flows" tending to improve the performance. It is found that because of the slipstream curvature, there is an additional upflow on the wing inside the slipstream. From this we can infer that these configurations will generate greater lift with less drag. These results are analogous to those observed with the jet flap, but further research is required to obtain quantitative estimates.

The influence of stream velocity gradients on airfoil characteristics has been investigated both theoretically and experimentally. The important conclusion reached was that one could not estimate the airfoil characteristics with any degree of accuracy using classical theories. One effect of the stream velocity gradients is similar to cambering the airfoil. That is, a symmetrical airfoil in a propeller slipstream will generate lift at zero angle of attack. For a typical slipstream, this lift coefficient would be about 0.5. Another effect observed near the slipstream axis of symmetry is that the slope of the lift curve is roughly doubled because of the velocity gradients.

Still another effect observed in two-dimensional experiments was that wing stall could be delayed by properly orienting the airfoil with respect to the slipstream. The test data shown in Fig. 4 indicate that by moving the airfoil from slightly above to slightly below the slipstream axis, the maximum lift is more than doubled. This effect has not yet been theoretically demonstrated, but it seems to be associated with the velocity curvature altering the airfoil pressure distribution and hence the boundary layer development.

A clear, quantitative picture of all STOL/VTOL configurations is not yet in hand. However, the completed research clearly demonstrates many effects intriguing both to the researcher and to the designer. The exploitation of these effects, and those still to be studied, will provide the means for making airplanes take off — straight up.

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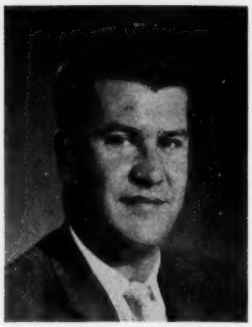
ABOUT THE AUTHORS



Dr. ALFRED BLUMSTEIN, author of "Air Traffic Control," has been occupied with air traffic problems over the past two years.

Dr. Blumstein's work at the Laboratory has also involved research in weapons systems analysis and evaluation, such as studies of the bomber-fighter duel, task group composition and disposition, and ICBM defense. He has also worked with the Office of Naval Research on ad hoc teams evaluating fleet air defense and missile systems.

A principal operations analyst and member of the technical staff in the Laboratory's Operations Research Department, Dr. Blumstein received his B.A. in Engineering Physics from Cornell University, an M.A. in Statistics from the University of Buffalo and his Ph.D. in Operations Research from Cornell University. He is a member of the Operations Research Society of America, the American Statistical Association, and Sigma Xi.

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A graduate of Massachusetts Institute of Technology in aeronautical engineering, Mr. Vidal has pursued graduate studies at the Oak Ridge Institute of Nuclear Sciences and at the University of Buffalo. Before joining Cornell Aeronautical Laboratory, he was employed as an aerodynamics engineer for the Fairchild Engine and Airplane Corporation, NEPA Division. In addition to the aerodynamics of STOL/VTOL aircraft, his work at the Laboratory has included studies of aerodynamic heat transfer, aerodynamics of low-aspect-ratio wings and unsteady boundary — layer separation. He has also devoted considerable time to feasibility studies of hypersonic shock tunnels and their instrumentation.

Mr. Vidal is a member of the Institute of Aeronautical Sciences.

RECENT CAL PUBLICATIONS

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"NEW THERMOMECHANICAL RECIPROCITY RELATIONS WITH APPLICATION TO THERMAL STRESS ANALYSIS," Biot, M. A.; CAL Report No. SA-987-S-7; June 1958; 30 pages.

Based on the variational formulation of linear thermodynamics as developed previously, thermomechanical reciprocity relations are discussed which lead to new methods of analysis of thermal stresses. These reciprocity relations are quite different from the usual ones derived from the analogy of thermal loading with a combination of surface and body force distribution. The results are applicable to stationary and transient temperatures in elastic and viscoelastic structures.

"THE TAILORED-INTERFACE HYPERSONIC SHOCK TUNNEL," Witliff, Charles E.; Wilson, Merle R.; and Hertzberg, Abraham; Reprinted from the Journal of Aero/Space Sciences, Vol. 26, No. 4; April 1959; 9 pages.

The "tailored interface" hypersonic shock tunnel provides a means for producing the high Mach Number, high stagnation temperature flow conditions encountered in hypersonic flight. Various gasdynamic phenomena associated with shock tunnels are discussed, and experimental evidence of the successful application of this technique is presented. As an indication of its research application, the results of heat transfer experiments on a hemisphere-cylinder model are presented and compared with theory.

"PRELIMINARY RESEARCH ON A MOLECULAR-BEAM FOR THE 1-10 EV RANGE," Skinner, George T.; and Treanor, Charles E.; CAL Report No. AD-1118-A-9; December 1959; 61 pages.*

This report presents an interim discussion of the design and construction of a molecular-beam apparatus for the production of atomic and molecular beams in the 1-10 ev energy range. A shock tube is used as the source of high-temperature, high-pressure gas, and a hypersonic expansion is used to obtain a high-energy, nearly mono-energetic beam.

"SIMILITUDE OF HYPERSONIC REAL-GAS FLOWS OVER SLENDER BODIES WITH BLUNTED NOSES," Cheng, Hsien K.; Reprinted from the Journal of Aero/Space Sciences, Vol. 26, No. 9; September 1959; 10 pages.

On the basis of the hypersonic small-perturbation theory, the laws of similitude for hypersonic inviscid flow fields over thin or slender bodies are examined, and the restrictions to ideal gases with constant specific heats and to bodies with pointed noses are removed. Only steady plane or axisymmetric flows are considered.

"TRACK FORCE MECHANICS IN DEFORMABLE SOILS," Clark, Daniel C.; CAL Report No. YM-1198-V-1; March 1959; 40 pages.

Soil and track mechanics necessary to the motion analysis of track-laying vehicles are reviewed, and existing theory is extended to permit the prediction of forces and moments acting on a track that is yawing and sideslipping in deformable soil. It is proposed that a circular soil bin with a "whirling arm" mechanism be built to perform force measurements on a track that is both turning and moving longitudinally with respect to the ground plane.

"A QUALITATIVE FLIGHT TEST INVESTIGATION OF SOME HANDLING QUALITIES ON LIAISON TYPE AIRPLANES," Rhoads, Donald W.; CAL Report No. TC-1214-F-1; September 1959; 110 pages.*

A series of flight tests has been conducted for the purpose of determining, from pilot opinion data, the relative acceptability of various amounts of stick-fixed and stick-free static longitudinal stability. Two test vehicles were used, both liaison types, one modified for boundary layer control.

"AN INVESTIGATION OF THE INFLUENCE OF NON-LINEAR TRANSFER FUNCTION ON CATHODE-RAY TUBE VISUAL DETECTION THRESHOLD," Miller, C. W. and Minty, W. R.; Reprinted from the IRE National Convention Record, Vol. 7, Pt. 9; 1959; 11 pages.

The intensity modulated Cathode Ray Tube (CRT) is a non-linear device whose output brightness varies approximately as the 5/2 power of input signal voltages. This transfer function is not optimum for many applications and experiments have been performed by inserting a variable transfer function into a closed-loop television and a simulated radar system, respectively. The non-linear transfer function of the cathode ray tubes was thereby modified and the effect of different transfer functions of the systems was evaluated as it related to minimum detectable threshold signal.